INDIAN CENTRAL JUTE COMMITTEE

AGRICULTURAL RESEARCH BULLETIN NO. 2.

JUTE BREEDING EXPERIMENTAL TECHNIQUE

(SELECTION AND HANDLING OF BREEDING MATERIAL)

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Published by the Secretary
INDIAN CENTRAL JUTE COMMITTEE
4, HASTINGS STREET, CALCUTTA.
1945

Price Rs. -/8/- or 9*d*.

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I. INTRODUCTION

Success and speed in plant breeding depend upon the utilization of methods and technique appropriate to the crop. In jute, a number of minor problems in breeding arise from its being a fibre crop, grown under a set of trying agricultural conditions. The two species of *Corchorus* i.e. *C. capsularis* and *C. olitorius*, from which the jute fibre of commerce is obtained, are grown in deltaic areas in India, which have a low altitude, below 50 feet, and a small gradient. Part of this huge jute area is *char* or low lands, which are inundated from over-flow from the rivers early in the monsoon. Other jute areas, known as 'medium lands' located on a higher level than the *char* lands, are inundated later in the season in July and August. On these two types of lands, *capsularis* is exclusively grown, as this species of jute is tolerant to water logging, while *olitorius* is not. The rest of the jute growing tract, known as 'high lands' grows all the *olitorious* crop and some of *capsularis* as well. These high lands do no get flooded. In breeding jute for, and in such varying terrain, the breeder has to face a number of obstacles regarding labelling, recording of observations, harvesting, etc., which have to be overcome. Jute crop has a short vegetative period and is grown during the wettest part of the year, with a rainfall of 50 to over 100 inches in that period. Between sowing and harvest of the crop there are a few spells of dry weather, during which, all field work, observations, records etc. have to be completed. It is very warm and humid in a jute field, and the breeder has to work under a great strain.

In *C. olitorius*, it has been found necessary to protect the breeding material against foreign pollination. The height of the plants, which at the time of flowering is well over six or seven feet makes selfing a difficult major field operation. Jute being a fibre crop, has to be harvested long before the seeds mature, which itself brings in a number of breeding problems.

Plant breeders, all over the world, have to be systematic and precise in timing their field operations and observations, but in jute, the need for rigid adherence to a planned time-table is even more necessary than in many other crops. From the experience gained in jute breeding work at Dacca and its substations, a definite technique and system have been evolved, which it is felt may be of some interest to workers on bast fibres.

The authors are aware that the paper contains some obvious small details of procedure, with which any breeder is expected to be conversant, The only justification for their inclusion is the fact that these seeming trifles, in a crop like jute, assume considerable importance in the successful completion of the season's programme.

II. SELECTION AND TESTING OF BREEDING MATERIAL

SELECTION

As jute is a fibre crop, harvested long before the seeds mature, both fibre of good quality and seed cannot be obtained from the same plant. If it is harvested at the proper stage of fibre maturity, no seeds can be obtained, If on the other hand, fibre extraction is delayed till seed maturity, the plant becomes dry, does not ret properly and fibre extraction is unsatisfactory. Since a selected plant has to be kept for seed and its fibre content cannot be determined, it is necessary to base selection on some morphological characters which are known to influence the fibre yield most. Two such characters in jute are its height and thickness, the correlation coefficient of the two with the yield of fibre being +0·761 and +0·914 respectively ; the greater the height and greater the thickness of the stem, the larger is the outturn of fibre.

On 1000 plants of strain D. 154, plant height and base diameter were measured, the plants were then retted and fibre from each extracted and weighed. Out of these, 97 plants had a height of 190 cm or above, their fibre yield ranging from 3·5 to 16·4 gms ; 77 plants had a base diameter of 16·0 mm or above, and there were only 36 plants which had a height of 190cm or above as well as a base diameter of 16·0 mm or more. The fibre outturn of these 36 plants ranged between 6·5 to 16·4 gms *vide* table given below.

Classes of fibre yield in gms.	Frequencies of plants selected on		
	Plant height 190 cm. or above.	Base diameter 16·0 mm or above.	P.H. & B.D. 190 cm & 16·0 mm or above respectively
15·5 – 16·4	1	1	1
14·5 – 15·4	2	2	2
13·5 – 14·4	3	4	3
12·5 – 13·4	3	4	3

Classes of fibre yield in gms.	Frequencies of plants selected on		
	Plant height 190 cm. or above.	Base diameter 16·0 mm or above.	P.H. & B.D 190 cm & 16·0 mm or above respectively.
11·5 – 12·4	2	4	2
10·5—11·4	6	12	6
9·5 – 10·4	9	13	8
8·5 – 9·4	14	15	4
7·5 – 8·4	20	12	6
6·5 – 7·4	15	5	1
5·5 – 6·4	12	4	...
4·5 – 5·4	7	1	...
3·5 – 4·4	3	—	...
Total	97	77	36
Mean fibre yield ...	8·4	9·8	10·7

It will be seen that the mean yield per plant advances to 10·7 when both the characters are considered. These characters are convenient to work with. Tall plants are easily spotted in the field and their diameters can readily be measured.

Conditions of jute cultivation are such, that over a large part of the jute growing tracts, it is very difficult to retain single plants for seed. The breeder has therefore to make all initial selections at his breeding centres. Consequently, a large collection of bulk samples is essential.

These samples are grown on a field scale replicated varietal trial. The material is then studied, for yield and other characters such as earliness, plant height, base diameter, pigmentation etc. Primary field selections on the basis of height and thickness are made from the material in the trial over all the replicates. After the study of yield and other characters is completed, the initial selections are narrowed down to those belonging to promising types in the trial. The earliness, height and diameter records of these selections are further studied and only the best performing plants on these characters are finally kept.

Primary selections and secondary or reselections in the cultures should be taken up as early as possible. The field work in connection with these selections can be taken in hand when the crop is 2 to 3 months old, and should be completed before flowering, so that selfing of the selections, where necessary, may not be delayed and plant records can be made at the proper stage.

In jute, the amount of seed available, varies from less than a gramme to about 12 gms per selection. Reasons for this considerable variation are (1) the care taken in seed collection (2) vigour of the plant and (3) the locality where it is grown. At Dacca the yield of seed per plant is always lower than in any of the other three jute breeding centres i.e. Kishoreganj, Narayanganj and Konda.

Testing of breeding material

For a progressive sifting of the primary selections, controlled and rigorous testing is introduced from the very beginning, which is continued right up to the final varietal trial stage.

In the first year the selections are tested in replicated progeny rows. Experience gathered in the last few years, in conducting replicated progeny row trials, indicates that good results are obtained when (1) the number of cultures are about fifty, (2) plots are 20 feet long having two rows one foot apart, (3) plant to plant distance is fore inches, (4) and there are 8-10 replications. For a good stand it is best to sow a minimum of two seeds per growing point. If quantity of seed permits, sowing of three seeds per hole is desirable. The plots may be arranged in one or two or more ranks as convenient, so as to make the block as compact as possible. A layout of this magnitude for a *capsularis* trial requires, 1920 to 2400 seeds or 6·4*—8 gms. of seeds depending upon whether there are eight or ten replications. Two non-experimental rows on the exposed sides of the layout are sown and in each row two plants on either end are kept as non-experimental margin. After the seeds have germinated and seedlings have established themselves, the plants are thinned to single plant per growing point. This gives 896 to 1120 experimental plants per culture.

Though the above layout for a replicated progeny row trial is recommended, it is recognised that such a layout may not always be possible due to lack of seeds. Adjustments to meet the seed available may be done in the following order: (1) the plant to plant distance within the row may be increased to six inches, (2) the number of rows per plot may be reduced to one (3) the length of the plot may be reduced up to 10 feet (4) replcations may be reduced up to six. The expedients enumerated above may be tried singly or in combination. For a *capsularis* trial having single row 10 feet plots, plants six inches apart, six replications, and sowing two seeds per point, the seed requirement is 240 seed or 0·8 gms. Such a small layout should only be designed under exceptional circumstances. As, at any time, there are only a few selections with such small quantities of seeds, it would be more profitable to grow single plots of all such material, and make fresh selections in them. If possible, all adjustments in the size of the trial should be done by changing the plant to plant distance and the number of rows per plot. The number of replications should be kept as high as possible and the length of the rows should be kept as near 20 feet as possible. With this length the standard error per cent of yield corrected for stand is below 10 per cent, *vide* table given below.

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* 1 Gramme of seed—300 seeds of *capsularis*, 500 seeds of *olitorius*.

No. of cultures.	Length of row.	No. of rows per plot.	No. of replications.	S. E. %.
43	10′	1	6	8·5
75	10′	1	6	11·3
93	10′	1	6	13·1
124	10′	1	8	11·9
34	10′	1	9	6·2
21	10′	1	10	9·2
93	10′	1	10	17·9
51	10′	2	6	8·9
90	10′	3	6	12·8
106	12′	2	6	10·6
38	16′	2	6	10·5
28	18′	1	8	7·4
44	18′	2	8	8·0
25	20′	1	10	7·2
36	20′	2	8	5·5
40	20′	2	10	4·1
58	20′	2	10	8·5
33	20′	4	10	8·3
56	20′	5	8	7·7

Owing to the limitation in the number of selections that can profitably be tested out in one trial, due to the variability in the amount of seed available per selection, and owing to the need to classify the selections on earliness character, it becomes necessary to conduct two or three or even more replicated progeny row trials at a time.

For secondary selections, equal number of plants from all the replications are selected on eye judgement. These as well as the remaining plants are measured for their height and diameter. Omissions in selections are made good. Leaving out the secondary selections the plot is harvested and fibre extracted after retting. On the basis of mean values of yield of fibre of progenies, promising ones are retained. The secondary selections of these promising progenies are further thinned down on the basis of height and diameter deviations from the plot mean to which they belong. Thus two selection pressures are exercised (1) progeny selection pressure giving the best progenies on actual yield performance (2) plant-selection pressure giving individual plants on height and diameter performance.

The plant-breeding technique advocated here is the same as that recommended by Huchinson and Panse (1937), except for the indirect selection of individual single plants.

In the second year the selections are tested in compact family blocks, which enables the sister progenies to be grouped together into families.

Six to ten families with four to eight progenies in each and eight to ten replications may be included in a single layout of this type. The comparisons are for selecting the most promising families and in the families the most promising progenies. To propagate the selection, individual plants are chosen in the manner described above.

Testing and sifting of the selections is continued in compact family block layouts till the genetic variability has fallen low, or in other words a stage has been reached in some families when the differences between the progenies within the family are not significant. When this stage in reached the progenies of such families are bulked up for trial as a strain.

From the small bulk trial stage onwards the strains are sown broadcast instead of in lines as was done in the earlier stages of breeding. The usual seed rate for broadcast fibre plots is 10 lb. to the acre for *capsularis* and 6 lb. for *olitorius*. These may, if necessary, for such trials be reduced to 8 and 5 lb. per acre respectively. Seeds obtained by bulking the sister progenies (coming from a compact family block trial) are adequate for a small bulk trial in 1/100 acre plots with 8-10 replications. If necessary, the replications may be reduced to six. A two feet non-experimental margin should be left all round the plot. After the small bulk trial stage there would be enough seed to conduct a full scale varietal trial on 1/40 or 1/50 acre plots in two or three localities.

III. SEED

Seed multiplication

In the earlier stages of breeding, in replicated progeny row and compact family block stages, no separate seed plots are necessary, as seed multiplication goes on simultaneously. For example in a 20 feet, two row plot and ten replicate progeny row trial, four secondary selections are made per plot, i.e. from all the replicates 40 plants are kept from which seeds are to be collected. By the time the seeds are mature some casualties would have occurred among these plants and seeds from perhaps 30 plants will be available. The final secondary selections are now made and perhaps six will be carried forward for trial in compact family blocks. In small-sized replicated progeny row trials, fewer secondary selections are made. In a ten feet single row trial, only one secondary selection should be made. In the compact family block trials reselections are made in each progeny.

At the small bulk trial stage, if the preceding compact family block trial was of six progenies per family, having 20 feet single row plots and ten replications, with two selections per plot of each progeny, seed from 120 plants should be collected. When the sister progenies are bulked this would give 1 to 1½ lb. of seed.

From the small bulk trial stage onwards, separate seed plots of the strains have to be grown. Seed multiplication in jute is on the average 20 times. If ¼ lb. of the available seed of the strain is reserved for seed multiplication, it would multiply to 5 lb., the seed plots being sown at the rate of 5 lb. per acre.

Seed collection

In cotton, wheat and many other crops, seed is collected automatically with harvest of the crop; but in jute, as the economic product and the means of propagation are different, with an interval of six weeks or more between the maturity of the two, seed collection is laborious and time consuming.

Jute seeds are ready for collection, by early October, and should not be delayed too long, as the capsules are likely to split and the seeds scatter, particularly in *olitorius*. Further, late rains favour the appearance of fungi on ripe pods, which reduce the germination capacity of the seeds. Care should be taken not to collect seed from any dead or diseased plants. After threshing, winnowing and cleaning, they should be thoroughly dried in the sun. Two or three sunnings are necessary, and after each sunning, the seeds should be allowed to cool down before they are put back in their containers.

IV. PLANNING AND PREPARATION

Planning

As soon as the analyses and examination of the data are completed the seeds of the culture to be grown and studied further, should be taken out and carefully sieved and sifted. All bad and shrivelled seeds should be rejected and only good ones retained. This examination of the seeds is important, for getting an accurate idea of the seed of each culture available, and for ensuring a good stand in the plots. Only after this final examination, the weights of seeds of each culture, should be recorded. With the completion of seed weighing, the planning of the experiments for the coming season can be undertaken. For each experiment details of layout, observations etc. should be worked out and embodied in a scheme, a specimen of which is shown below;

Specimen schedule of experimental scheme.

1. EXPERIMENT — First year Capsularis trial No. 1—1944.
2. SITE — Narayanganj.
3. OBJECT — To test yield performance of primary selections (early) coming from the district materials grown at Narayanganj in 1943.
4. Materials to be grown.

Selection.	Source.	Description of selections.				Remarks.
		Pigmentation Grade No	P. H. inches	B. D. cm.	Earliness Date of first flower	
6	C. T. 283-42	1	108	3·0	9-7-43	
7	,,	1	114	2·9	,,	
9	,,	1	117	3·1	,,	
18	,,	1	114	2·7	,,	
20	,,	1	108	2·9	,,	
23	,,	4	114	2·6	,,	
35	,,	1	114	2·9	1-8-43	
36	,,	1	114	2·9	,,	
37	,,	1	106	3·1	,,	
38	,,	1	118	2·9	5-8-43	
39	,,	1	112	3·6	1-8-43	

Selection.	Source.	Description of selections.				Remarks.
		Pigmentation Grade No	P. H. inches.	B. D. cm.	Earliness Date of first flower.	
43	C. T. 267-42	1	113	2·4	1-8-43	
47	„	1	114	2·8	„	
49	„	4	102	2·8	16-7-43	
51	„	4	106	3·2	„	
53	„	3	114	3·6	„	
54	„	1	98	4·2	„	
56	„	3	103	3·3	„	
59	„	1	112	2·6	„	
62	„	2	113	3·5	16-7-43	
63	„	1	103	3·0	„	
65	„	1	102	3·1	30-7-43	
87	C. T. 257-42	1	108	3·1	„	
105	C. T. 258-42	3	114	2·3	„	
107	„	3	105	2·8	17-7-43	
117	„	3	108	2·5	„	
132	C. T. 323-42	1	108	2·4	1-8-43	
165	C. T. 336-42	0	102	2·8	15-7-43	
171	„	0	106	2·8	25-7-43	
180	„	0	98	2·7	„	
D 154	Control	1	—	—	Late	
Fanduk.	„	1	—	—	Early	

In all 32 treatments (including two controls),

5. LAYOUT.—Replicated randomized double-row plots in eight blocks. Blocks = 42′ × 32′ each arranged in two ranks of four blocks each. There should be no paths between blocks within rank, but one path only 5′ wide between ranks of blocks. Plots = double-row, each row 20′ long. Rows one foot apart arranged in two ranks within the block with a 2′ path between ranks of plots. Non-experimental—two plants at each end of a row. Two rows of D 154 at each exposed side of the layout to be grown parallel to the experimental plots. Sowing of these non-experimental D 154 lines should be done the same day and in the same way as the experimenal plots. Total area of eight blocks = (42′ × 32′) × 8 = 0·247 acre.

6. PRESOWING OPERATIONS.—Ploughing and manuring as usual.

7. METHOD OF SOWING.—Seeds to be hand dibbled in rows 20′ long having holes 4″ apart, giving 60 holes per row.

8. SEED RATE.—Two seeds per hole or 240 per plot of two rows.

9. POST-SOWING OPERATIONS—(1) Weeding as usual (2) Thin to single plant per hole immediately after pigmentation records have been checked.

10. RECORDS TO BE KEPT.—(1) Date of sowing.

(2) Germination record—plot-wise.

(3) Check up pigmentation per plot. (This is a check on sowing)

(4) Date of first flower per plot.

(5) Vigour performance—3 stages (early before flowering and after flowering.)

(6) Date of harvest.

(7) Harvest stage.

(8) Stand per plot.

(9) Dates of steeping and extraction.

(10) Fibre weight per plot.

(11) Notes on season, condition of the crop, incidence of diseases and insect pests.

11. SEED COLLECTION.—Select two best plants (avoid border plants) per plot or 16 plants per culture. Record flowering date, pigmentation, P.H., B. D., & F. W. collect seeds of all selected plants separately.

N.B.—Daily record of flowering is not necessary, but *it must be taken once every week* for all cultures.

12. RANDOMIZATION AND PLAN.—Not shown.

Preparation.

Seed should be counted or weighed out separately for each plot and each row. After these seed packets are made, they should be arranged for each experiment according to randomisation and stored till the time of sowing.

This pre-sowing preparation and planning take time. At Dacca, experience has shown that 2—3 months are needed for this. The work should be taken up as early as possible after the examination of data so as to be ready in good time for the sowings, which are uncertain.

Labelling.

In this crop considerable attention has to be paid to small details, such as labelling. The followings are the types of labels needed.

(*a*) Plant labels
    (*i*) Permanent (*ii*) Temporary
(*b*) Retting labels
(*c*) Plot labels.

(a) *Permanent plant labels.*—Jute plants are tall, usually over 6 feet in height, and like sunn hemp are grown thickly packed together. During the vegetative period of the crop the weather conditions are severe. A label meant for marking primary and secondary selections and other seed plants should (1) be able to withstand alternate periods of strong sunshine and heavy rain and (2) be conspicuous, so that the labelled plants are not harvested along with the fibre plants which are cut flush with the soil usually a month and a half before the seed crop reaches maturity.

Experience at Dacca has shown that labels for such purposes are best made of old kerosene oil tins, cut into 2″×1″ pieces and painted with black Japan. The labels should bear large prominent numericals written in white enamel. The number of such labels used depends on the amount of work. On an average we have used 8000 such labels a year at Dacca. Apart from renewal due to losses, these labels last easily for three years after which a fresh coat of paint has to be applied and numbers rewritten.

Temporary plant labels. When plants are required to be marked for a short period only, as in classification of F_2 progenies, temporary plant labels can safely be used. Small paper tags serve the purpose admirably. We usually cut up No. 8 paper tags 6″ × 3″ size, into smaller bits one inch square or even smaller, depending on the purpose for which the labels are required. After writing they are paraffined and will serve for a month or so.

(*b*) *Retting labels.*—After harvest, the plants are made into bundles of about 100 plants each, steeped and retted before the fibre can be extracted. The process of retting takes 12-25 days depending on the weather conditions. After extraction, the fibre of the bundle has to be cleaned and dried before it is possible to record its weight. During all these processes from bundling of the plants to the final weighing of the fibre, which may take a period of two or three months, the identity of the individual bundle has to be maintained. For this purpose brass or alluminium labels 2″ × ½″ size stamped with numericals are found to be very useful. The numericals on such labels become indistinct after two or three seasons and the brass labels become black and discoloured and have to be renewed. Owing to the scarcity of the metal and the present prohibitive cost, we are now using mud labels 2″ × 1″ in size, baked hard in the furnace, with the numerical engraved before baking. Yearly requirements of retting labels at Dacca are on the average of 7000.

(*c*) *Plot labels.*—These labels are used for distinguishing the various plots, and 1200 or so are required for a season.

Small tin or brass labels 2″ × 1″ with numericals painted or stamped are useful. In high land areas the plot labels are tied to bamboo stakes 1½ feet long planted on the left hand corner of the plots. In low land areas which are inundated, the flood water rising to four or 5 feet, the labels have to be tied to tall bamboo stakes above the flood water level; or they may be tied to a rope strung between two poles at a distance of 8 to 10 feet.

V. CULTURAL ASPECTS

Pre-sowing

Jute seed is very small and for its sowing a fine tilth is required. This is generally accomplished by six to eight ploughings with a country plough. After each ploughing the clods are broken, the land levelled and weeds collected by running a *moi* or ladder over the field. The *moi* is made of bamboo and is 7 to 8 feet long. The operator weighs the *moi* by standing on it while it is being worked, During the course of preparatory tillage any manure that is to be applied is worked into the soil. In inundated areas which are annually enriched by silt, no manuring is necessary; in other parts, well rotted cow-dung at 100 maunds per acre is applied. On the Dacca Farm, where the soil is deficient the following manures are applied.

(*a*) Lime at ten maunds per acre,

(*b*) about a fortnight later, cowdung at 100 maunds per acre and bone-meal at three maunds per acre.

(*d*) Muriate of potash at 200 lb. per acre (100 lb. K_2O) a couple of days before sowing.

The task of transferring the layout from previously prepared field maps to the field, begins after the final preparation of land has been completed. At this stage, the positions of various experiments and their blocks can be marked out, but the finer details can be filled up only at the time of the sowing.

Sowing.

Jute is mostly sown with the pre-monsoon showers known as 'Norwesters'. The sowing season extends over a long period, depending upon the type of land. In low lands the sowing is done early, from mid-February to middle of March. In medium lands the sowings are later, usually from middle of March to end of April, and in high lands from May till about the middle of June. The sowings at Dacca are usually done after a good heavy 'Nor-Wester', giving over an inch of rain, towards the middle of April for *capsularis* experiments and in May for *olitorius* experiments. It is not advisable to sow *olitorius* experiments earlier than May.

For broadcast sown experiments the land is ploughed up, final layout completed, and immediately after sowing the plots are harrowed and laddered. For line sown experiments land is ploughed, laddered, the layout completed and the seed hand dibbled. Each sower is given a strip of bamboo as long as the plot and bearing appropriate spacing marks. At each mark he is to drop the required number of seeds. After sowing the seeds are covered by laddering the plot.

Mistakes in line-sowings are not unusual and can be avoided (1) by distributing seed packets and checking them before the sowing starts (2) by placing the used packet at the end of the plot before shifting the sower to next plot and (3) by checking empty packets when the sowing of a rank or a block is completed.

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*Low land jute is frequently over-run by water hyacinth. To protect the crop against this weed, waves and high wind, Dhaincha—*Sesbania aculeata* border four to five feet all round the experimental field has been found very useful.

In broadcast sown plots, when the plants are 3 to 9 inches high, the land is lightly harrowed two or three times with an *achra* or a rake. This breaks up the crust and destroys some of the young weeds. As jute is sown thickly this does not affect the stand. During the early stages of the crop, it is weeded two or three times by means of a *khurpi*. Along with the weeding, thinning is done for proper spacing and removing weak and diseased plants. After the final thinning the plants are usually spaced 4 to 6 inches apart.

In line-sown plots weeding is done by wheeled hand hoes, such as Planet Junior hoes. They are very efficient in performance and cut down the cost of weeding by about 50 per cent. Normally, weeding is the most expensive item of jute cultivation comprising about 55 per cent of the total cost of production of fibre. After the first hoeing, it is necessary to use a *khurpi* to weed in between the plants within the row. A few women working behind the hoe can do this very speedily.

VI. RECORDS AND OBSERVATIONS.

Immediately after the sowings have been completed the plots should be labelled. As all records and observations hinge on the completion of this piece of work it should not be delayed. Before sowing, each plot should be allotted a label and a record kept in the experimental record books. It is a good practice to arrange the labels of an experiment accordig to its randomisation, as this ensures accuracy and speed in actual labelling of the plots. After the completion of labelling, the labels should be checked over and mistakes rectified.

Germination.

With proper moisture conditions jute seeds germinate quickly. Most of the seeds sprout within two or three days, and the germination is complete in five or six days. With the completion of the labelling of the cultures, a survey of the germination in various experiments should be undertaken. This should be done plot-wise and need only be described in general terms, as good, fair, poor etc.

If the germination is gappy, no attempt should be made to fill in the gaps by resowing, as experience has shown that, even when the gap filling has been done within ten days of the original sowing, the resown plants are poor and lag behind, never catching up with the original sown plants in vigour and height. Gap filling by transplanting has been found to be more satisfactory than resowing. All transplanting should be done on wet days and within a month of sowing the crop. The earlier the transplanting is done, the better is the success. As 2-3 seeds are sown per hole, the material for transplanting can be obtained from these extra plants. If the germination is poor in an experiment, the only really effective measure is to plough up the whole experiment and resow. To ensure good stand one must (1) use only well developed plump seed (2) sow the experiment under good conditions and (3) sow 2-3 seeds per sowing point in the line-sown experiments.

Pigmentation.

There is considerable variability in the expression of this character, the genetics of which has been dealt with by Patel and his co-workers (1944) and need not be described here. As it forms an excellent criterion for a check up of the cultures the pigmentation performance of the culture should be noted as soon as possible after germination record. Plants are not ready for this record till they have attained a height of nine inches. From the pigmentation performance, sowing mistakes, if any, are brought to light, whether a culture is segregating or accidental mixing has occurred is determined, and any natural crosses in open pollinated cultures are shown up.

Roguing should be based on pigmentation performance. For the roguing to be thorough, it is necessary to go over the plot two or three times and it is best done before the plants have grown taller than the eye level of the worker. Thinning to one plant per sowing point should be taken up immediately after the first roguing has been done.

Vigour study.

To evaluate potentialities of the cultures a study of the vigour of the various cultures should be carried out, at least at three stages of their growth, viz. (1) at an early stage when the crop is about 2 feet high, (2) before flowering and (3) at flowering. The procedure is to inspect each and every plot in a block with a view to judge the height and thickness of the plants. When a plot is better than the neighbouring ones, that culture is allotted a point, After all the blocks are covered, the points are added up and comparison is made with the points scored by the control. For example in a compact family layout, if there are 6 progenies in each family and if there are ten replications, the total possible points for the family will be sixty and for a progeny ten. Owing to differential rates of growth, it sometimes happens that cultures scoring high in the first vigour study, drop down in later studies and *vice versa*, while others maintain their ranks. Vigour study is particularly useful in locating promising parental stocks, and will assist by avoiding unnecessary seed collection of and observations on inferior cultures.

In the three characters described below there is considerable variability. These characters have a direct bearing on the yield of the crop and consequently are of economic importance. They should always be included in the programme of observations to be taken on the cultures.

FLOWERING.

Soon after flowering, the plants are mature and ready for harvest. The duration of the vegetative period varies considerably, ranging from 50 days or less from sowing to 120 days or more. A good idea of the duration of the vegetative period of a culture can be obtained by recording plot-wise the date of the first flower opening in each culture. A record of such a nature enables the worker to judge the earliness and suitability of his culture for trials in various jute growing areas. Further, the worker can judge, how soon certain of his cultures will be ready for harvest.

PLANT HEIGHT

For recording this important character the technical height or length of the undivided stem should be taken. At maturity, the jute plants may be 5 feet or less in height to 10 to 12 feet or even more. Plants as tall as 16 to 17 feet have been recorded, but, such extraordinary heights are rare and are due to exceptional environmental conditions. The taller the plant the greater the yield it gives, the correlation co-efficient of yield and plant height being +0·761. The height record should be taken only after the vegetative period is over and the plant has entered the reproductive phase.

THICKNESS OF THE STEM

Like height, the thickness of stem is also very variable, mature plants may be 1″ to 1½″ or more thick. Thickness of the stem is highly correlated with fibre yield, the correlation co-efficient being +0·914. Records on this character should be taken at maturity along with the plant height. The thickness or the diameter of the stem should be measured just above the soil surface.

MINOR CHARACTERS

In the four characters described below the variability is limited, and they need not form part of the routine schedule of observations and records to be taken, unless they are involved in any of the cultures.

BRANCHING HABIT

All Indian jutes branch, while some foreign *capsularis* do not (Patel *et all*, 1944). The latter is a very desirable character to breed into the Indian jutes. Branched and non-branched plants can be distinguished at an early stage.

POD-SHAPE

In *capsularis* the pods are usually round but in some types they are oval (Ghose 1942) In *C. olitorius* the pods are cylindrical. Observations on this character, if any, can be taken only when the plants are mature and pods well formed.

COROLLA COLOUR.

Jute flowers are generally yellow but pale-yellow flowers are quite common (Patel *et all*, 1944). It may often be necessary to include this character in the programme of observations to be taken on the cultures.

STIPULE CHARACTER

In some foreign *capsularis* types the stipule is foliaceous, which is simple recessive to the normal stipule (Patel *et all*, 1944). So far no instance of foliaceous stipules occurring in Indian jutes has been met with.

OTHER RECORDS

At harvest, stand and green weight per plot are recorded. After the bundles have been retted, the fibre is extracted and dried. Fibre weights are now recorded and fibre percentage i.e. the ratio of fibre to green weight calculated. Details regarding these records are given in the section on harvesting and preparation of fibre.

VII. SELFING AND CROSSING

INFLORESCENCE

The inflorescence is a leaf opposed, condensed cyme occurring on the terminal and lateral branches. The flowers are in groups of two to three in *C. olitorius*, two being common. In *C. capsularis*, they are in groups of two to six, three being common. While in both the flowers are small, those of *C. olitorius* are much bigger and about twice the size of *C. capsularis*. The difference in size of the flowers is so marked that the two species can be distinguished on this character alone. In both the species the calyx and corolla are usually 5-merous, but in *C. olitorius* 6-merous and even 7 or 8-merous flowers may be found. In *C. capsularis* the number of sepals and petals are more constant, 6-merous flowers being rare. Stamens are numerous and surround the stigma. Ovary is five locular, rarely more. In *C. capsularis* there are two rows of ovules in a loculus, each row consisting of usually five ovules, while in *C. olitorius* there is a single row, usually of forty ovules.

SELFING

In *C. capsularis* the flowers are mostly self pollinated, but some cross pollination does take place, which is usually below 5 per cent, and mostly

2 or 3 per cent. In extreme cases, the natural crossing percentage may go up to ten. In *C. olitorius* where the flowers are larger. bigger and remain open longer than *C. capsularis* flowers, the extent of natural crossing is greater, being on the average about 12 per cent (Ghose and Das Gupta, 1944).

While it has not been found necessary to protect capsularis breeding material against natural crossing, it is necessary to control pollination in *olitorius*. To protect the plants against foreign pollen, mesh cloth bags 2′×1′ are being used. The bags are fitted with two bamboo rings, one at each end about 8″ inside dividing the bags into three more or less equal portions. One piece of string about 1½ feet long is tied to the closed end of the bag and another is threaded to the mouth of the bag, so that it can be closed when required. *C. olitorius* plants are normally more than seven feet tall having inflorescence mostly at the top. If only a few plants have to be selfed all that is necessary is to plant a long bamboo by the side of the plant, and to suspend therefrom the bag on to the plant and close it by drawing in the string and tying it to the plant. The rings in the bag prevent the walls from collapsing and touching and injuring the flowers. When however a very large number of plants have to be selfed, as in breeding work, a scaffolding or a frame-work with upright and horizontal bamboos is much more economical. Care should be taken that the top string is not taut as owing to wind there may be sufficient strain on the plants to damage them. The method for selfing jute plants requires an elaborate arrangement and is quite expensive. Owing to the partial seclusion of light and air and the higher humidity inside the bags, the setting of pods is less than usual.

CROSSING TECHNIQUE

The female parent should be free from stem rot, chlorosis or attack by mites, as such plants often die before the crosses mature or the cross-pods do not develop properly.

As early flowers set better, they should be used as female parents. All buds in an inflorescence, except the one to be emasculated, should be removed. The bud that will open first in an inflorescence is the best material for emasculation. Immature and young buds should never be emasculated, a bud ready for emasculation can be recognised by its size. Its anthers and petals are yellow, while in an immature bud the petals have a whitish appearance, and the anthers have a slightly reddish look. Further the filaments in an immature bud are much shorter and the anthers below the level of the stigma. As the bud develops the filaments grow rapidly pushing the anthers to the level of the stigma or slightly below it.

To minimise the chance of selfing, emasculation should be done twenty four hours before the opening of flowers i.e. the previous day, though it is difficult and it needs careful work owing to small size of buds and presence of numerous stamens.

Jute flower is sensitive to removal of calyx and corolla, particularly the former; setting is extremely poor when calyx is removed. Morning is the best time for pollination, up to 9-30 a.m. for *olitorius* and upto 11-0 a.m. for *capsularis.*

The anthers dehisce by longitudinal slits. Artificial pollination is best done by holding the flower by its stalk with a forceps and then lightly touching the stigma with the anthers of the male flower, till the stigma is covered with pollen, which can easily be observed with a hand lens.

Small-sized oil-paper bags have been found to be suitable for covering flowers before and after pollination. These bags are able to stand light showers of rain or wetting by dew during the night. Bags should be removed 24 hours after pollination.

If repetition is necessary, it should be done early in the season. Failures may be detected, better with the help of a hand-lens, on the third or the fourth day after pollination. Such young capsules appear discoloured and shrivelled up. It sometimes happens that the young crossed pod stops growing after a time. In such cases prunning of other pods on the branch gives stimulus to the crossed pod which then develops to its normal size.

The interval between opening of the flowers and maturity of the pod is about 6 weeks. Appearance of brown spots, streaks or patches on the pod indicates that the pod will soon be ready for collection, time of collection being indicated by uniform browning of the pod. Crossed pods should be collected as ready, otherwise, there is risk of loss of seed by splitting particularly in case of *C. olitorius.*

VIII. HARVESTING AND PREPARATION OF FIBRE

STAGE OF HARVEST

As the development of the fibre takes place during the vegetative period of the plant, and practically ceases with the onset of reproductive phase, the jute plant may be harvested at this stage.

With the onset of the reproductive phase, the stem bifurcates at the top and floral buds are produced. This transition from vegetative to reproductive phase is gradual in a plot, as all the plants do not reach this stage simultaneously. To obtain the best yield from a plot, it therefore becomes important to judge the maturity of the crop. Experience has shown that the best stage for harvest is reached when 50 per cent of the plants are in small pods. Both outturn and quality are good at this stage. If the crop is harvested earlier than this, the yield is low, or if the harvest is delayed and the pods become big or start ripening, the fibre obtained from the crop is coarse. Judgment of the proper stage of harvest comes with a little experience and familiarity with the crop. It is important that the date of first flowering in the plot is recorded and then onwards the crop is regularly examined and watched. Fifty per cent flowering should be noted, as soon after this stage, the crop will be ready for harvest.

In the low land areas, jute is normally harvested at an earlier stage, usually at flowering or even earlier due to the following reasons :—

(1) When there is high flood and the crop is in danger of submersion and consequent loss.

(2) Even *C. capsularis* cannot stand water logging for very long. When flood water enters the jute field, the plants adapt to aquatic conditions by growing adventitous roots, and the submerged portions of the stem become swollen and spongy. If the water logging continues for some time the plants start rotting and die.

(3) When after a sudden rise the flood water recedes to a lower level, a clear mark is left on the stem due to formation of bark. This portion of the stem does not ret properly and the fibre produced therefrom is defective.

(4) Flood water may enter the field unusually early.

Harvest period of jute extends from about the end of June in the low land *capsularis* areas to the end of September in the high land *olitorius* areas.

HARVEST

The preparation for harvesting should be done well in advance of the actual operation. The non-experimental borders of the trials should be marked when the crop is less than two months old, the earlier the better. At harvest stage the plants are 6 feet or more in height, hard and resistant to free movement among them. In the early stages the plants are young and pliable and the work can be done easily and smoothly. The harvest plots should be pegged out and then roped. Coir rope which lasts without rotting till harvest time can be used for this purpose. The rope demarcating the harvest plots should be straight, taut and as low as possible, six inches above the soil being just right for the purpose. Roping should only be done by skilled labour under strict supervision.

In low land trials, the ropes demarcating the harvest plots should be tied to long bamboos and the rope raised along these poles as the flood water rises. In line-sown layout no preliminary roping of harvest plots is necessary.

In harvesting jute the plants are cut close to the ground with sickles. For an average crop 18 men are enough to harvest an acre, when the crop is good, the plants thick and tall, 24 men per acre may be utilised. The plants after cutting are tied into bundles about 9" in diameter for steeping. In order to retain the identity of the bundles through all the stages of steeping, extraction, drying and weighing of fibre, the bundles have to be labelled. Before harvesting an experiment, an estimate of the number of bundles each plot would yield should be made, and appropriate number of labels allotted to each plot in the trial. A 1/40th acre plot of normally grown crop gives 20-25 bundles. The labels should be serially arranged in bunches for each plot and distributed in plots before the plants are actually cut. In this operation only effective plots are cut, and the non-experimental borders left standing. As soon as the harvest of one plot is finished, the cut plants are made into bundles of appropriate size, labelled and left lying in the plot arranged in order in a row. The labels should be securely tied to the bundle, so that, it does not drop off in subsequent operations of steeping etc.

GREEN WEIGHT

Immediately after bundling and labelling the green weight of the individual bundles should be recorded. The green weights are taken on a pan balance or a spring balance and should be done as rapidly as possible. On no account should the bundles be left lying in the field for any length of time before recording the green weights, as evaporation is very rapid from cut plants. With proper planning, harvesting and recording of the weights can proceed simultaneously. Care should be taken that men cutting and bundling the plant are never more than two plots ahead of the men recording the green weights.

After recording the green weight, the bundles are stacked in the plots for 72 hours. The bundles are either kept flat on the ground in such a way that the bare stem portion of a bundle is covered by the leaves of another bundle or the bundle may be kept standing. The purpose of stacking is to shed the leaves before the bundles are removed for retting.

STAND

The number of plants in a bundle is recorded in order to get the stand per plot. This may be done on the day of the harvest after the green weight record, or during the period when the bundles are kept stacked.

The best way to have the bundles counted is to ask the labourer doing the work to count the number of plants in a bundle in sets of four. The man who is counting should not leave his bundle before its label has been checked and the total number of plants recorded.

In low land areas, if the flood water is low, harvesting can be done by standing in water. If the level of the water is high harvesting has to be done by diving. In one dive six to eight plants are cut. The harvested plants are bundled, counted and labelled. In low land areas it is neither possible to record the green weights of the bundles nor to stack them. After the harvest the bundles are either steeped in the field or carried in floats to a convenient steeping place.

EXTRACTION OF FIBRE

For steeping, the bundles are arranged in two or three layers in floats or 'Jak'. The surface of the 'Jak' is covered with weeds, grasses etc. and submerged by weighing it down with log of wood. The 'Jak' should be completely submerged about 4" to 6" below the level of water. Care should be taken to steep bundles from each experiment together and separated from those of others. The bundles of the experiment should be arranged according to blocks in the 'Jaks'.

Retting period varies from 12 to 25 days depending on the maturity of the crop, thickness of the stem and the temperature. After about 10 days the steeped material should be examined daily, to know the progress of retting. When the bark peels off clean from the stick, retting is complete and the material ready for the extraction of fibre.

Extraction should be bundle-wise. A labourer should never be given more than a bundle at a time and should be asked to extract fibre from each retted stem in the bundle individually. After all the stems in a bundle have been stripped and the fibre washed and cleaned the label should be tied to the fibre and bundle taken over from the labourer before stripping the next one. The fibre so obtained has to be thoroughly dried in the sun before the fibre weight can be recorded. It should be seen that the labels are securely tied, and the fibres of various experiments do not get mixed up.

After the bundles of fibres have been dried they should be sorted out, first blockwise, and then plot-wise, Fibre weight of the bundles should be recorded in a Barengers balance accurate to the nearest gramme.

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